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14. ABSTRACT This Annual Performance/Technical Report documents the research progress made under this grant during the respective time period. Student technical reports, task sheets, and instructor evaluations are attached to this report. Key advances in the technical and mentoring aspects of this work are highlighted.

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Annual Performance/Technical Report

Investigations into the Application of Cumulant Functions in Operations Research and Stochastic Modelling

Principal Investigator:
Timothy I. Matis, Ph.D.

September 9, 2003

Overview

The purpose of this report is to document research progress related to this grant. Specifically, this report covers the academic period from 16 September 2002 – 15 September 2003. The undergraduate student supported by this work through this time period is Martijn Kolloffel. Copies of student technical reports, task sheets, and sealed instructor evaluations are enclosed.

Undergraduate Research Course

As part of the requirement of this grant, Martijn was enrolled in the Industrial Engineering undergraduate research course for the Fall 2002 and Spring 2003 semesters; i.e. IE 300 and IE 400 respectively. Martijn was classified as a junior in Fall 2002 and a Senior in Spring 2003. In this course, we formally met every week for 2 hours. As the work progressed, however, we would often meet informally several other times during the week. As part of this course, Martijn was given both a set of specific tasks to perform and a general objective toward which he was to work. A specific task sheet was generated at the beginning of each semester, yet the tasks went far beyond those initially assigned as areas of needed concentration were identified. Martijn completed all tasks assigned to him exceptionally well and received a grade of an A for this work both semesters. The general objective on which Martijn was to also work was to formulate a model in which cumulant-based modelling would be useful. This would entail several hours of library research and the full development of knowledge maturity in stochastic processes. Due to his lack of previously work in this area, several hours were devoted to the basic understanding of stochastic processes and cumulant functions. This basic instruction spanned both the Fall 2002 and Spring 2003 semesters. At the current time, however, Martijn's knowledge in this area is sufficiently mature to pursue focused research in this area. We no longer focus on the basics of stochastic modelling in our meetings and have moved onto the formulation and analysis of a well defined research model.

Research Logs and Reports

Martijn was instructed to keep a weekly research log of accomplishment and future directions. On these logs, he was also instructed to indicate whether he had spent a minimum of 20 hours working on this research. These logs have proven to be very beneficial to Martijn in providing research continuity and direction. At the end of each semester, Martijn was also instructed to prepare a technical report chronicling the research conducted that semester and highlighting accomplishments that he had made. Though the reports had shortcomings in grammar and style, their content was sufficient to earn the grade of an A both semesters. These student technical reports are attached to this document.

Research Progress in Stochastic Modelling via Cumulant Functions

Martijn has made outstanding progress in his knowledge of stochastic modelling and the potential use of cumulant functions in such. Over the past two semesters, he has been introduced to the use of generating functions, phase-type approximations, moment and cumualnt generating functions, quasi-birith-death processes, and the underlying characteristics of common probability distributions. He has read the latest literature in the field and has learned to use Mathematica to implement computational routines for large models.

As with all research, there have been several discoveries that have been both positive and negative. In my experience, it is difficult for beginning researchers to have patience with the research process and to not panic when the "first" results are not what you would expect them to be. Martijn has developed a great deal of patience and maturity in the performance of research as this work has progressed. Specific research points on which Martijn was working the past semesters have changed considerably as results have been obtained. He has learned to both take these in stride and adapt to these changes towards the production of quality research worthy of publication.

Upon completion of the Spring 2003 semester, I impressed with Martijn's progress and decided to hire him to work on a NASA funded project over the summer related to the modeling of reliability systems. From this summer work, Martijn zeroed in on a application in which he would like to focus in the Fall 2003 semester. Specifically, he would like to work on the use of cumulant functions in reliability and/or system prognostics modelling. We have set a goal of submitting a paper and presenting this work at the Industrial Engineering Annual Research Conference in Houston, Texas in May of 2003.

Mentoring Activities

Over the past year, I have had the opportunity to attend several student mentoring workshops. These have provided me with several ideas and sources of literature for the effective mentoring of Martijn. Specifically, I have strived to develop a friendship relationship with Martijn that goes beyond this research. He and I frequently discuss our families, past experiences, and career goals in an open and two-way manner.

In the Fall 2002 semester, I provided Martijn with a guide titled "Pathways to the Ph.D.: A Handbook for Undergraduate Students and Their Mentors" produced by the Quality Education Network for Minorities. This book describes the expectations and potential benefits of graduate study to students by students themselves in a realistic manner. The process of applying for graduate school, taking needed exams, choosing an advisor, preparing theses, etc. is detailed for the student. I went over several parts of this book with Martijn and discussed his future plans with him. Though Martijn was opposed to the idea of pursuing graduate work in the Fall of 2002, he now indicates that he would like to pursue a master of science degree upon completion of his undergraduate degree. His actual pursuits will be documented and provided in the subsequent annual report.

Evaluations

As a student in the IE300/400 class, Martijn received an A for both the Fall 2002 and Spring 2003 semesters. Overall, he performed the research duties of this scholarship outstandingly well, and both his work ethic and quality of work are outstanding. Sealed instructor/mentor evaluations are attached to this document. Martijn was assured anonymity in these evaluations until he left the university. These evaluations were conducted by the departmental secretary and the original copies that reside with her are kept confidential.

Future Plans

Martijn is scheduled to receive his undergraduate degree in December 2003. At that time, a new student will be selected via the procedure described in the research proposal. I plan on starting this selection process prior to the close of the Fall 2003 semester so as to have the student work with Martijn in preparation for this research scholarship. There are several students in the department that have been through a basic stochastic processes course and are well prepared for this research. For the sake of research continuity, I hope to directly extend the model on which Martijn has been working with this new student.

Task Sheet – Spring 2003
Investigations into the Application of Cumulant Functions in Operations Research and Stochastic Modelling

1. **Library Research** – Locate, read, and summarize the following research articles and books
   a. Chapter 3 – *Stochastic Population Models*, Matis and Kiffe
   b. "Transient Analysis of State-Dependent Queueing Networks via Cumulant Function", Journal of Applied Probability vol. 38, Matis and Feldman
   c. Chapter on Cumulants – *Advanced Theory of Statistics*, Kendall

2. **Computer Training** –
   a. Complete Mathematica routine for the numerical approximation of the matrix exponential of a quasi-birth-death process
   b. Complete ProModel simulations of server failure-repair model under parameter specifications
   c. Formulate Mathematica routines for the generation of the ode's for the non-truncated cumulants of a simple stochastic model

3. **Model Formulation** – Work with the instructor in selecting an application suitable for cumulant-based modelling.
4. **Computer Application** – N/A until model specified

** This task sheet may be modified as the semester progresses at the discretion of the instruction. The addendums are noted below **

Task Sheet – Fall 2002
Investigations into the Application of Cumulant Functions in Operations Research and Stochastic Modelling

1. **Library Research** – Locate, read, and summarize the following research articles and books
   a. Read paper – "Using Cumulant Functions in Queueing Theory" Matis and Feldman
   b. Reach chapters 1-6 of "Introduction to Probability Models" Ross

2. **Computer Training** –
   a. Work Mathematica Tutorials – familiarize yourself with working with lists and solving ordinary differential equations
   b. Generate simulations using ProModel of the state of a tandem queueing network subject to blocking over the transient period

3. **Model Formulation** – Work with the instructor

4. **Computer Application** – complete training so as to implement model once specified

** This task sheet may be modified as the semester progresses at the discretion of the instruction. The addendums are noted below **